STAR Experiment at RHIC

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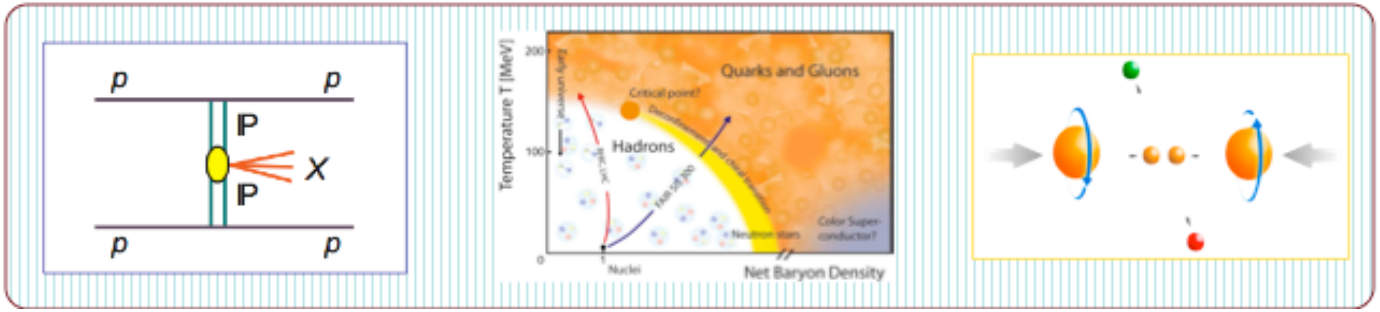
for the STAR Collaboration

Nuclear Science Division
Lawrence Berkeley National Laboratory



Outline

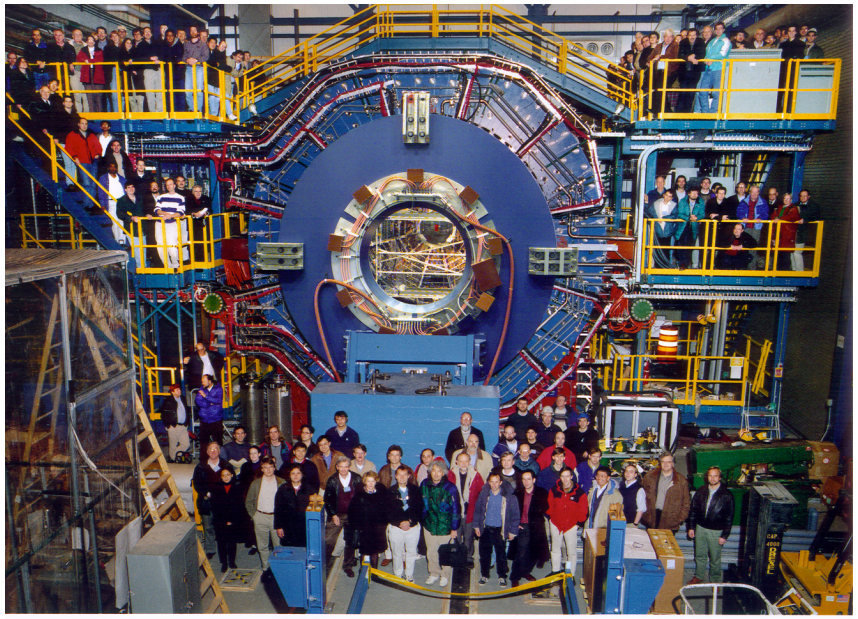
1) Introduction and the status of the experiment
2) Report on Run 9 and recent physics results
3) Upgrades and near future plans
4) Summary

STAR Collaboration Membership

U.S. Labs: Argonne, Lawrence Berkeley, Brookhaven
U.S. Universities: UC Berkeley, UC Davis, UCLA, *Carnegie Mellon*, Creighton, CCNY, Indiana, UIC, Kent State, MSU, Ohio State, Penn State, Purdue, Rice, Texas A&M, UT Austin, Washington, Wayne State, Valparaiso, Yale, MIT, Kentucky, Old Dominion U
Brazil: Universidade de Sao Paulo, Universidade Estadual de Campinas
China: IHEP, IOPP, USTC, Tsinghua U, SINAP, IMP, ShanDong U
Croatia: Zagreb U
Czech Republic: Institute of Nuclear Physics, Czech Technical U
England: U of Birmingham
France: *Institut de Recherches Subatomiques Strasbourg*, SUBATECH
Germany: Max Planck Institute, Frankfurt (BES)
India: IOP, Bhubaneswar, Jammu U, IIT-Mumbai, Panjab U, Rajasthan U, VECC
Netherlands: *NIKHEF*
Poland: Warsaw U of Technology
Russia: MEPHI, LPP/LHE JINR – Dubna, IHEP – Protvino, ITEP
South Korea: Pusan National U, KISTI

= Six new institutes joined in 08-09

= New institutes have applied for membership:
(1) HIT, China: two-particle correlation
(2) GSI, Germany: Hypernuclear production



13 countries
56 institutes
~ *620* scientists and engineers

Research topics at the QCD Lab:
- properties of strongly interacting matter
- proton spin structure
- gluonic matter

List of degree recipients: *103 PhD (and 20 other) degrees awarded on STAR research to students at 34 institutions*

Jammu University
2009 Neeraj Gupta, Ph.D

Max-Planck-Institut
2005 Frank Simon, PhD
2004 Joern Putschke, PhD
2003 Maierbeck Peter, Dipl.
2002 Markus Oldenburg, PhD
2000 H
2000
1998
1997
1997

Mich
2002

Ohio
2009
2004
2004
2003
2002

Pan
2008

Purd
2008
2007
2006
2003
2002

Rice
2006 Jianhang Zhou, M.S.
2001 Martin DeMello, M.S.

USTC China
2009 Zebo Tang, PhD
2007 Haidong Liu, PhD
2007 Yifei Zhang, PhD
2005 Xin Dong, PhD
2004 Shengli Huang, PhD
2004 Lijuan Ruan, PhD

IOP, Bhubaneswar
2007 R. Sahoo, PhD
2003 D. Misra, PhD
2005 A. Dubey, PhD

MEPhI, Moscow

SUBATECH
2007 Jonathan Bouchet, PhD
2005 Magali Estienne, PhD
2004 Gael Renault, PhD
2003 Ludovic Gaudichet, PhD
2002 Javier Castillo, PhD
2000 Fabrice Retiere, PhD
2000 Walter Pinganaud, PhD

2003 Haibin Zhang, PhD
2003 Michael Miller, PhD
2002 Matthew Horsley, PhD
2001 Manuel Calderon, PhD

IUCF
2008 Weihong He, Ph.D

SINAP
2009 Xinghua Shi, Ph.D
2009 Song Zhang, Ph.D
2008 Jin-Hui Chen, PhD
2006 Guoliang Ma, PhD

VECC
2008 P. Netrakanti, PhD

University of Bern
2005 Mark Heinz, PhD

University of Birmingham
2009 Thomas Burton, Ph.D
2008 Anthony Timmins, PhD
2008 Leon Gaillard, PhD
2005 John Adams, PhD

1999 Jie Lin, M.S.
1998 Quinn Jones, M.S.
1996 John Meier, M.S.
1995 Jeffrey Gross, M.S.

Texas A&M
2008 Michael Daugherity, Ph.D
2006 Thomas Henry, PhD

NIKHEF/Utrecht
2008 Federica Benedosso, Ph.D
2008 Martijn Russcher, PhD
2007 Yuting Bai, PhD
2007 Oleksandr Grebenyuk, PhD

Wayne State University
2006 Ahmed Hamed, PhD
2005 Ying Guo, PhD
2005 Alexander Stolpovsky, PhD

Nucl. Physics Inst., Prague
2008 P. Jakl, BS
2006 Jan Kapitan, M.S.

2005 Gang Wang, PhD
2003 Ben Norman, PhD
2002 Wensheng Deng, PhD
2002 Aihong Tang, PhD

LBNL
2008 Xiangming Sun, PhD
2007 Sarah Blyth, PhD
2007 Mark Horner. PhD
2003 Vladimir Morozov, PhD

LPP, JINR
2006 Alexei Zubanov, B.S.

115 Ph.D degrees
21 other degrees

(Since last review: 12)

STAR continues to do an excellent job of educating the next generation of physicists!

Blue = awarded 2008- 2009

Publications

Total # of refereed publications: 94 !

- *Phys. Rev. Lett*: 44, *Phys. Rev*: 38, *Phys. Lett. B*. 8, *J. Phys. G*: 3, ***Nucl. Phys. A*: 1**

Total # of citations: 8185 !

Number of Renowned (500+) 1

Number of Famous (250-499): 6

Number of Very Well Known (100-249): 18

Number of Well Known (50-99): 22

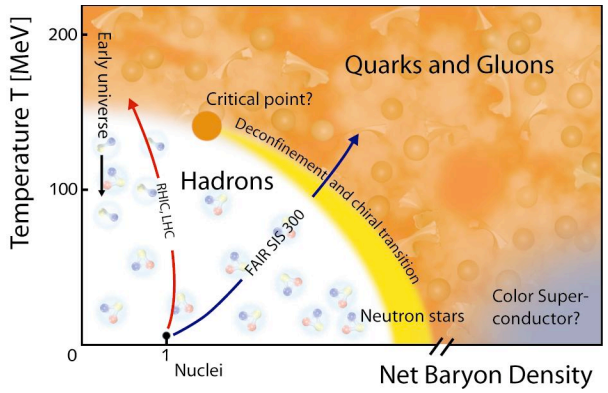
Total # of publications since last review: 12

- *Phys. Rev. Lett*: 5, *Phys. Rev*: 7 and 9 manuscripts are in referee process.

Total # of Quark Matter 2009 talks: 22+3

STAR is very productive!

STAR Physics Focus

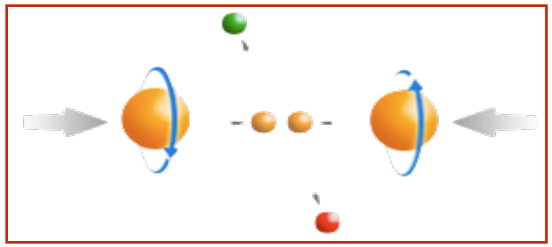


1) At 200 GeV top energy

- Study ***medium properties, EoS***
- pQCD in hot and dense medium

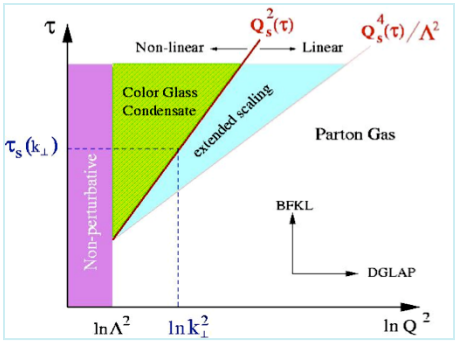
2) RHIC beam energy scan

- Search for the ***QCD critical point***
- Chiral symmetry restoration



Polarized spin program

- Study ***proton intrinsic properties***

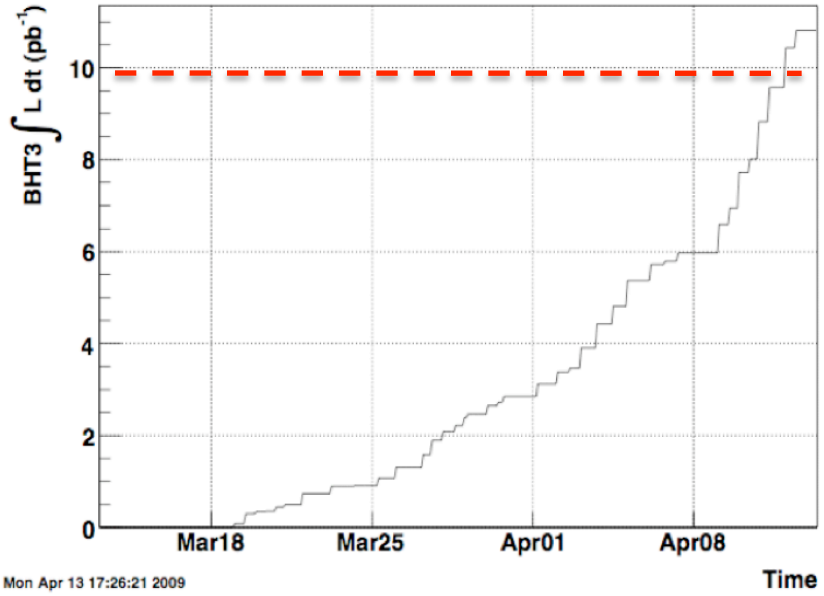


Forward program

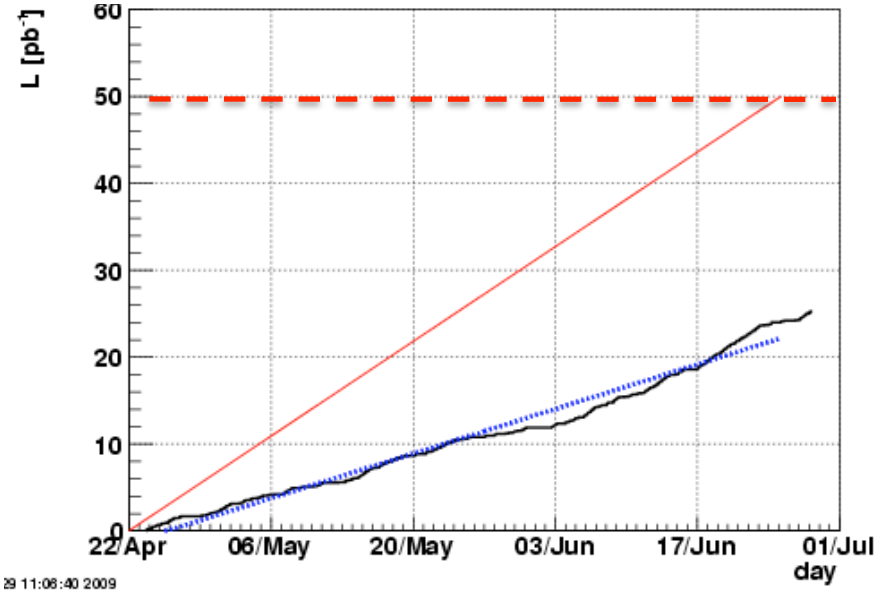
- Study low-x properties, search for ***CGC***
- Study elastic (inelastic) processes (pp2pp)
- Investigate ***gluonic exchanges***

Run 9

$\sqrt{s}$ = 500 GeV



$\sqrt{s}$ = 200 GeV



- Goal: $\mathcal{L}$:10 pb^{-1}, P$^2\mathcal{L}$: 2.5 pb^{-1}
- $\mathcal{L}$ goal reached: W Jacobian peak expected
- Polarization an issue
  - No significant A_L expected

- Goal: $\mathcal{L}$: 50 pb^{-1}, P$^4\mathcal{L}$: 6.5 pb^{-1}
- Reached: $\mathcal{L}$ ~50%, P$^4\mathcal{L}$ ~34%
- Minbias reference: x10
- Return in the future

500 GeV: Lessons learned

(1) Higher luminosity → stress on TPC

- Acute aging: high voltage trips
  - Largely alleviated by decreasing gain: made possible by DAQ1000
- Chronic aging: total integrated charge on wires
  - Studies ongoing to project from Run 9 into the future

(2) TPC review on June 4-5 2009 with outside experts

- 500 GeV: very challenging, reasonable solutions identified
- Detailed recommendations for study and possible alleviation scenarios received from the committee.

see talk by Jim Thomas

New Detectors in Run 9

Major changes in the detector: Fully commissioned

(1) TPC DAQ1000: replacement of entire electronics chain

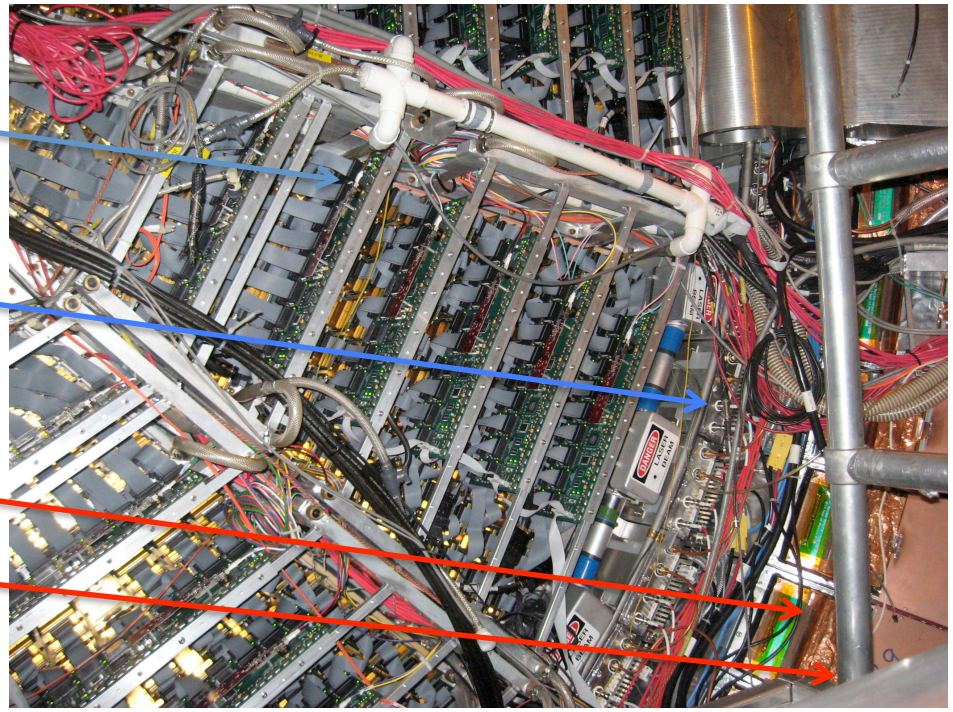
(2) ToF: 75% of trays in place

(3) EMC:

- Shower Max: modification of electronics to reduce deadtime
- Towers: rewire trigger to increase jet efficiency

(4) Trigger: New electronics (QT boards) for basic detector systems (BBC, ZDC, etc.)

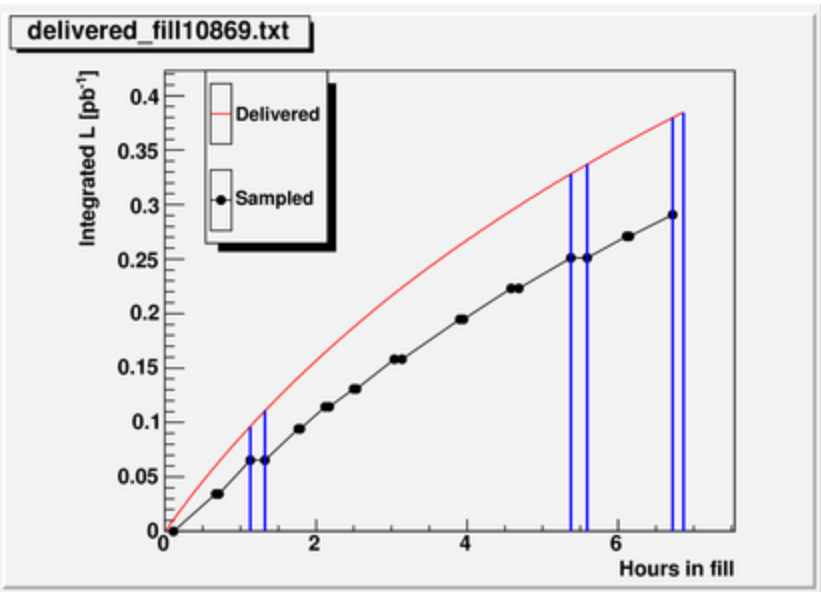
New Trigger Control Unit for greater flexibility



Overall goal: increase sampled/delivered ratio by lower deadtime

Largely successful: >90% livetime, best fills ~70% efficiency

Summary Efficiency Statistics



For the Entire 200 GeV run:

51.3 pb^{-1} delivered (C-AD 53.5)

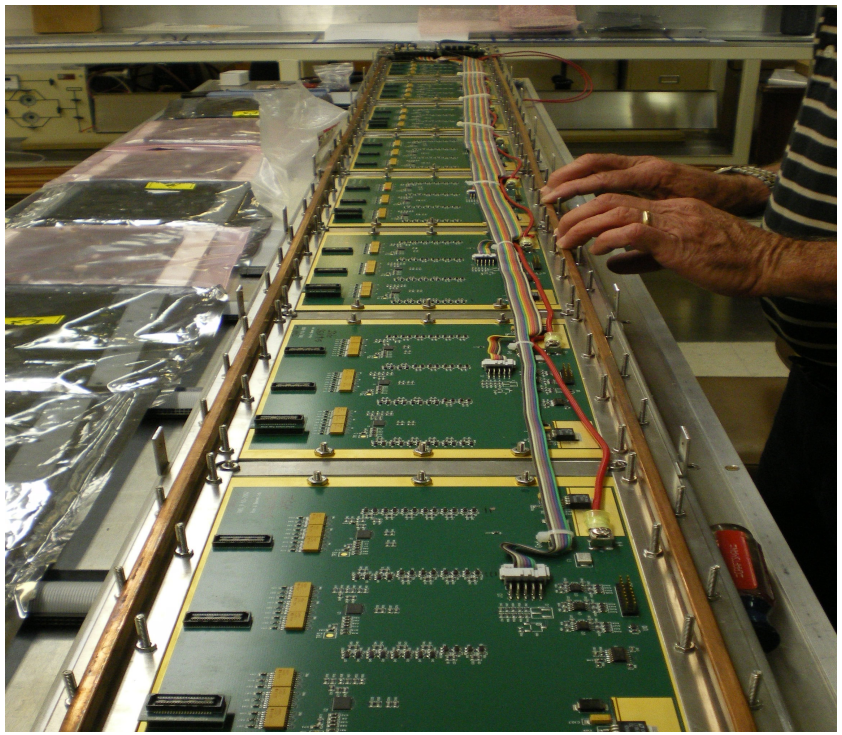
	Lum.(pb^{-1})	Ratio/delivered
Sampled	**25.3**	**47%**
Turn on phys.	8.4	16%
After turn off	3.6	7%
Lasers	5.4	10%
Deadtime	3.7	7%
Rest	7.1	13%

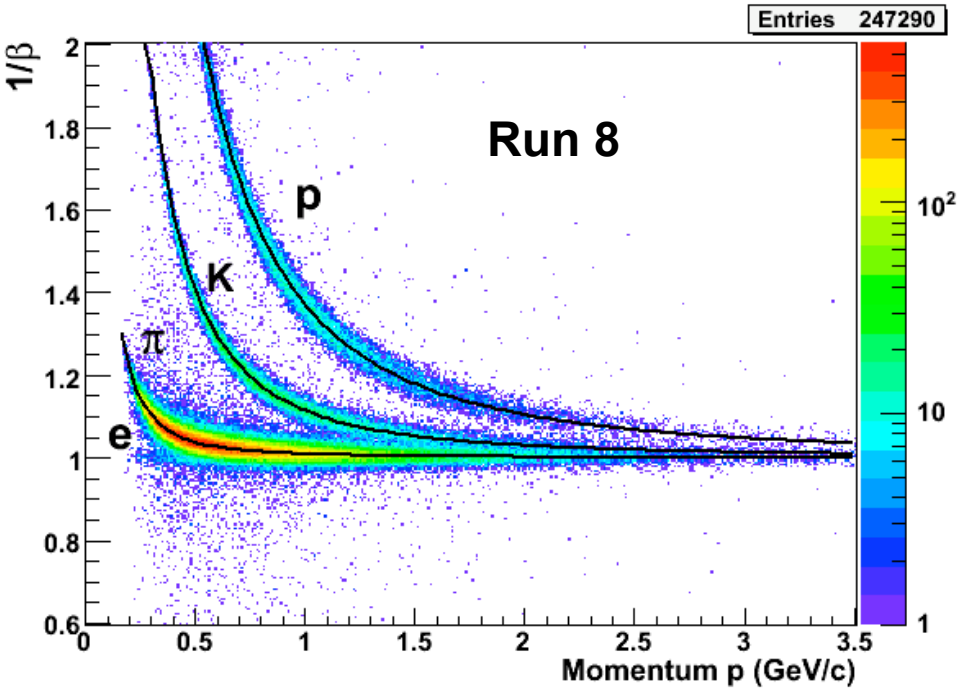
The overall efficiency increased by about a factor of 2!

Important that Shift crews get trained.

Important that physics running gets going before midnight!

STAR MRPC ToF and DAQ100

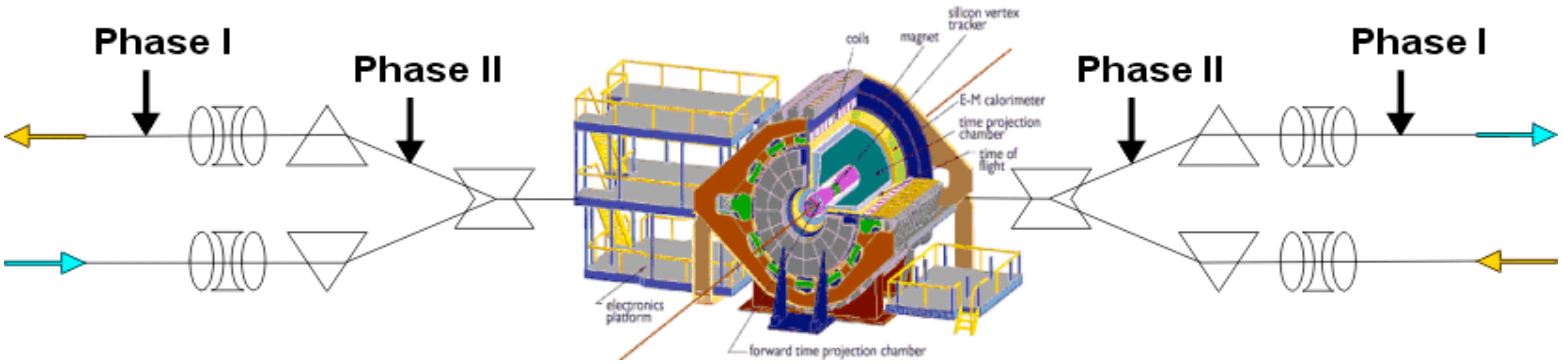


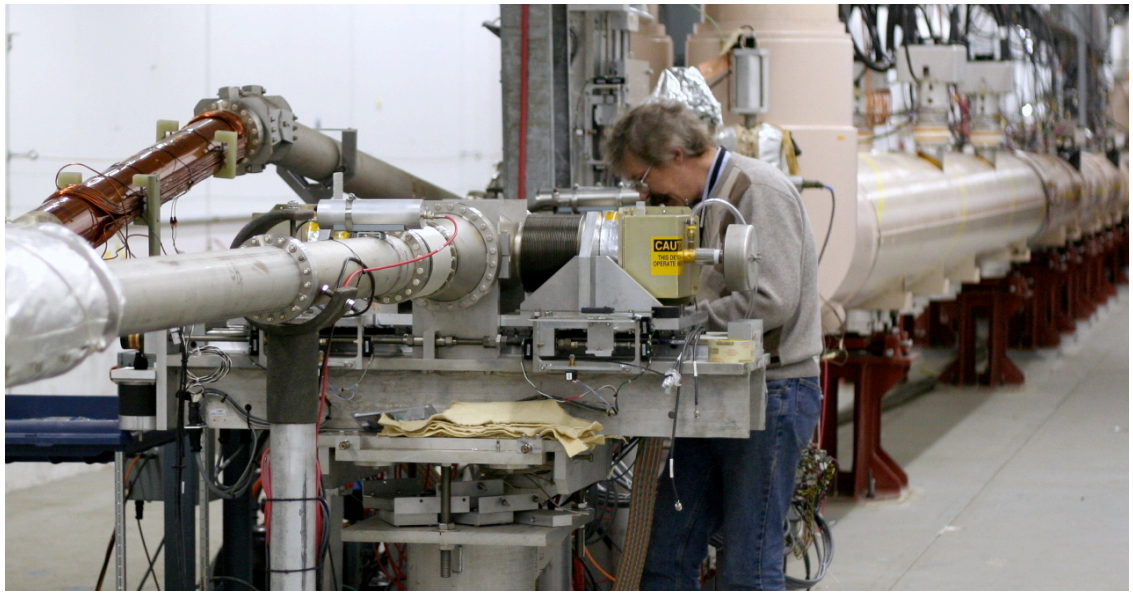


New in Run 9:

- 100% DAQ1000 TPC electronics took data
- 75% (90 of 120) ToF trays installed and took data in Run9
- 100% is planned before Run10

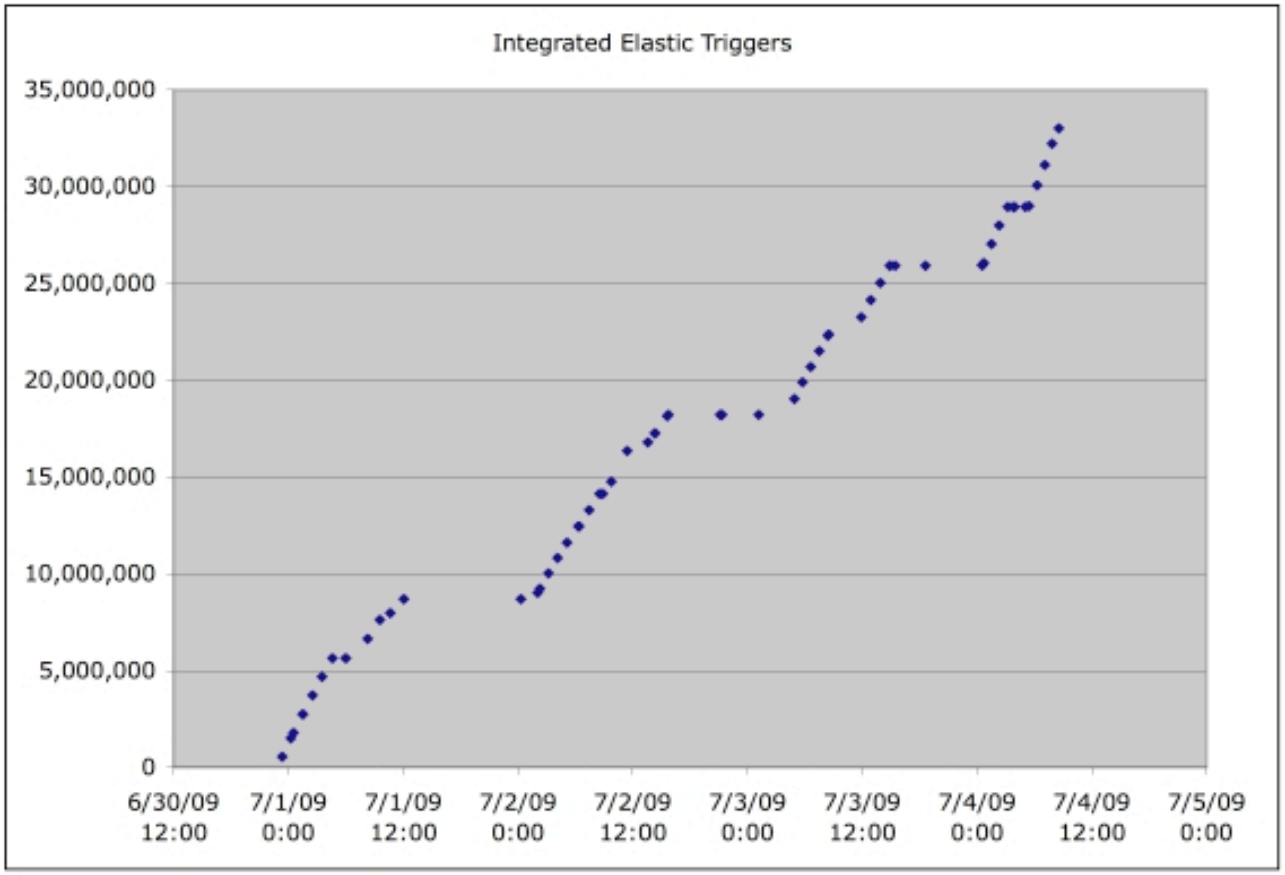
Run 9: pp2pp Data Taking





Many Thanks to C-AD who worked over the holiday weekend!

RUN 9: pp2pp Integrated Elastic Triggers



- Important part of STAR physics program

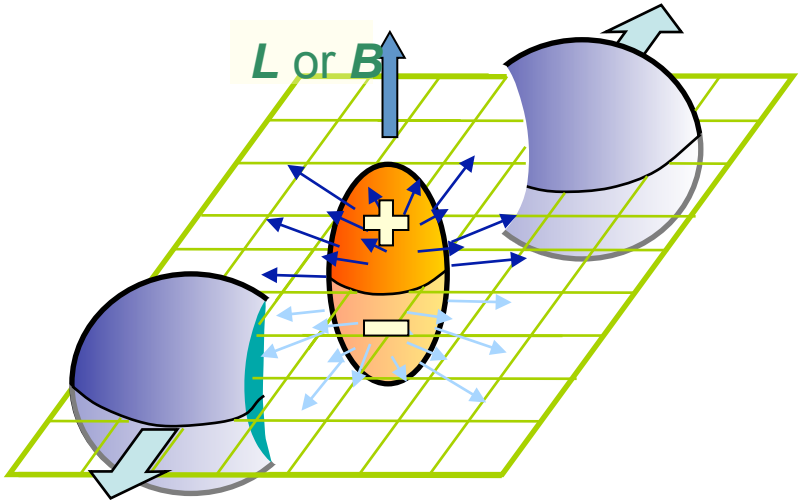
- 5-day dedicated pp2pp run, successful!

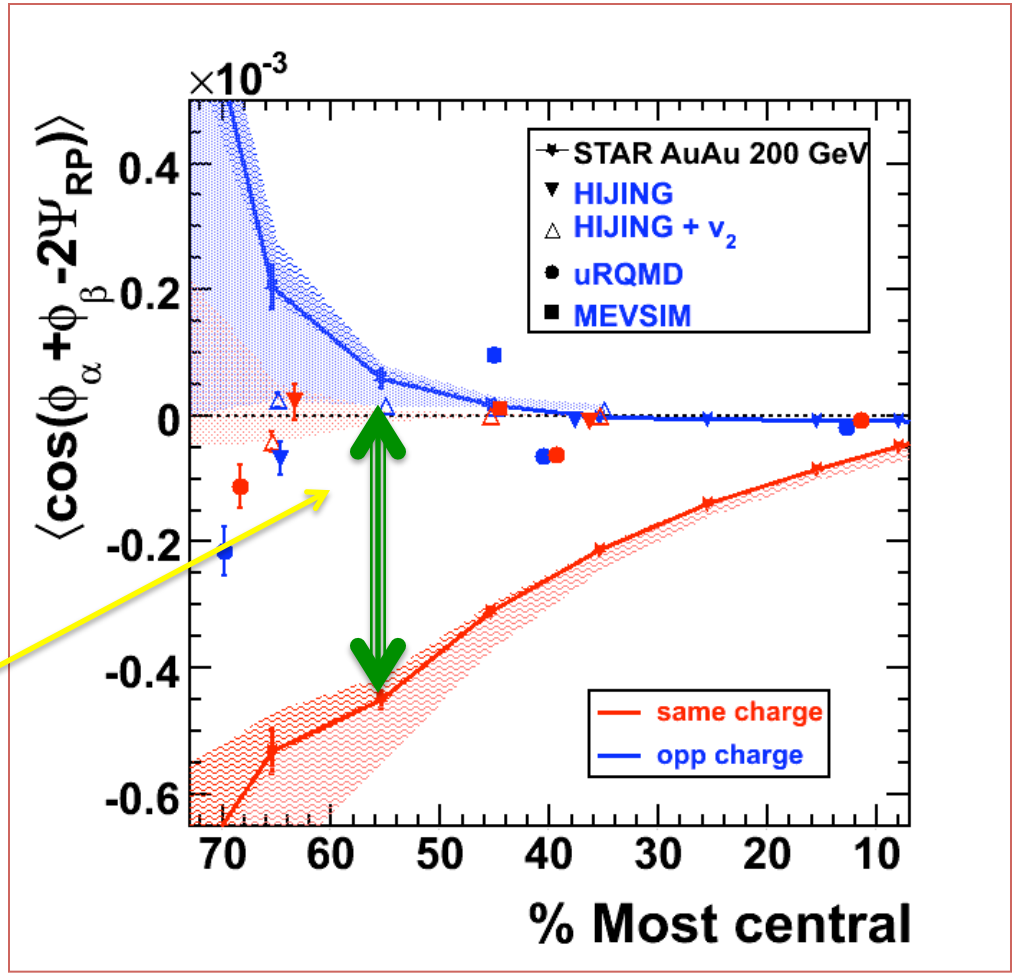
- Many thanks to C-AD who worked over the holiday weekend!

"We had a great run - the setup and its integration with STAR worked very well (35M elastic triggers, 700k CP triggers)"

Wlodek Guryn at the STAR Analysis Meeting, July 11th

Search for Local Parity Violation …



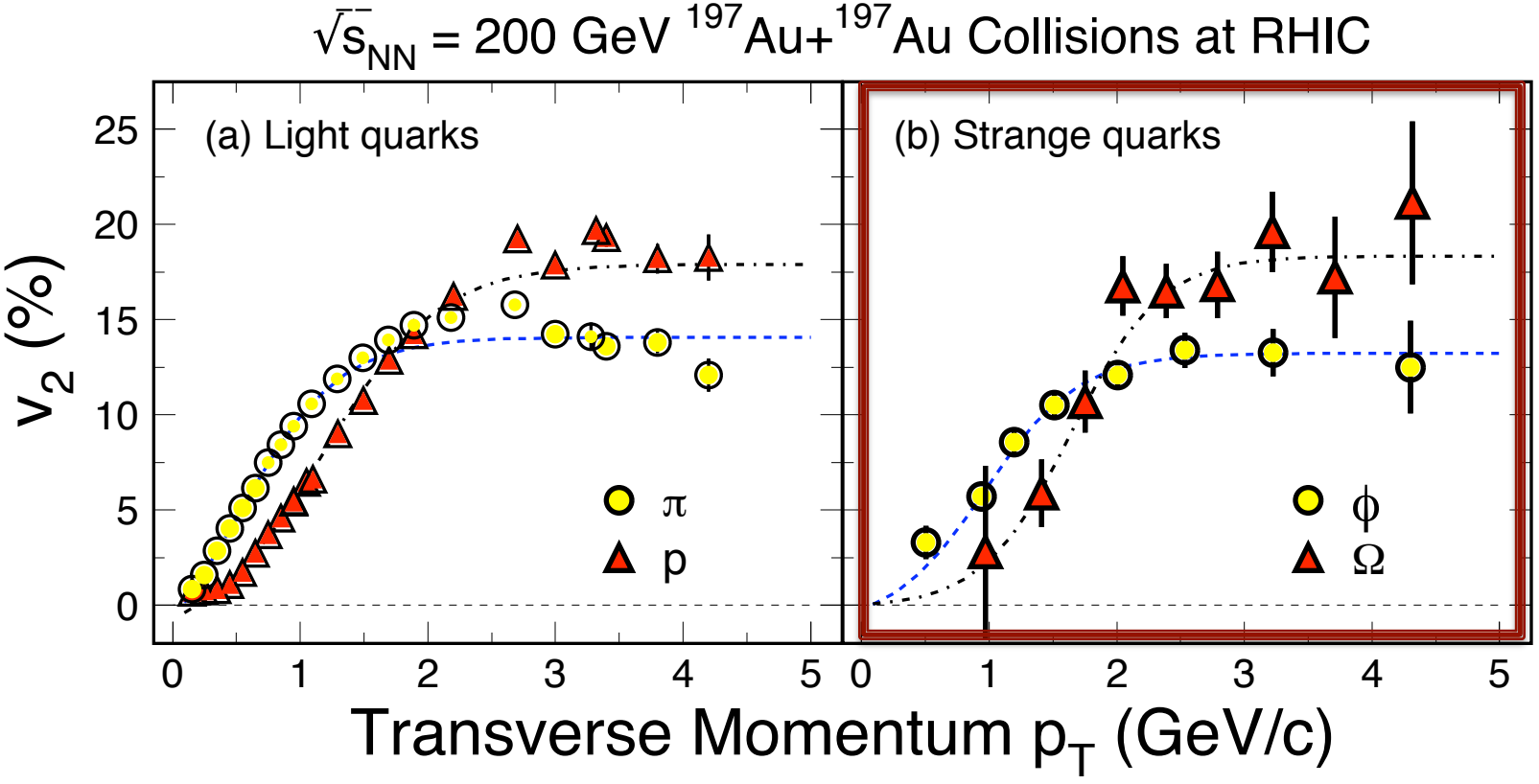


The separation between the same-charge and opposite-charge correlations.

- Strong EM fields
- De-confinement and Chiral symmetry restoration

Papers (PRC, PRL) in STAR review

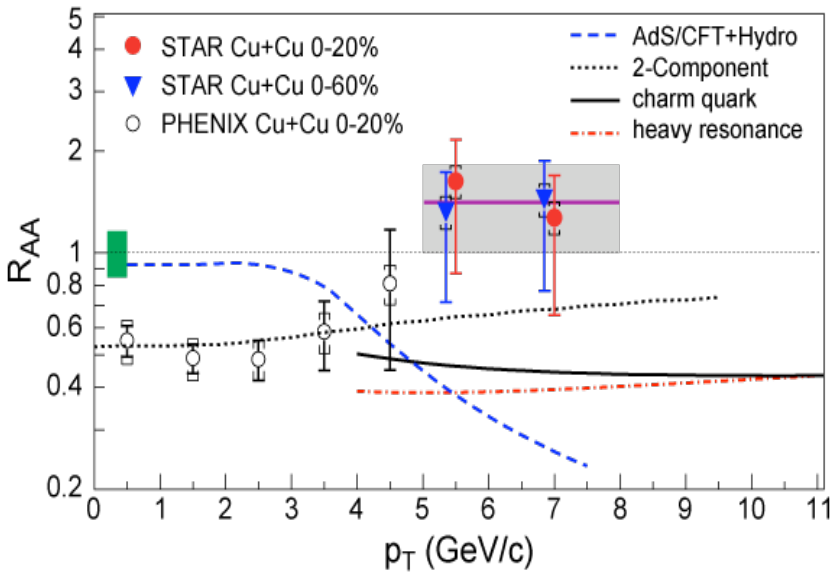
Partonic Collectivity at RHIC



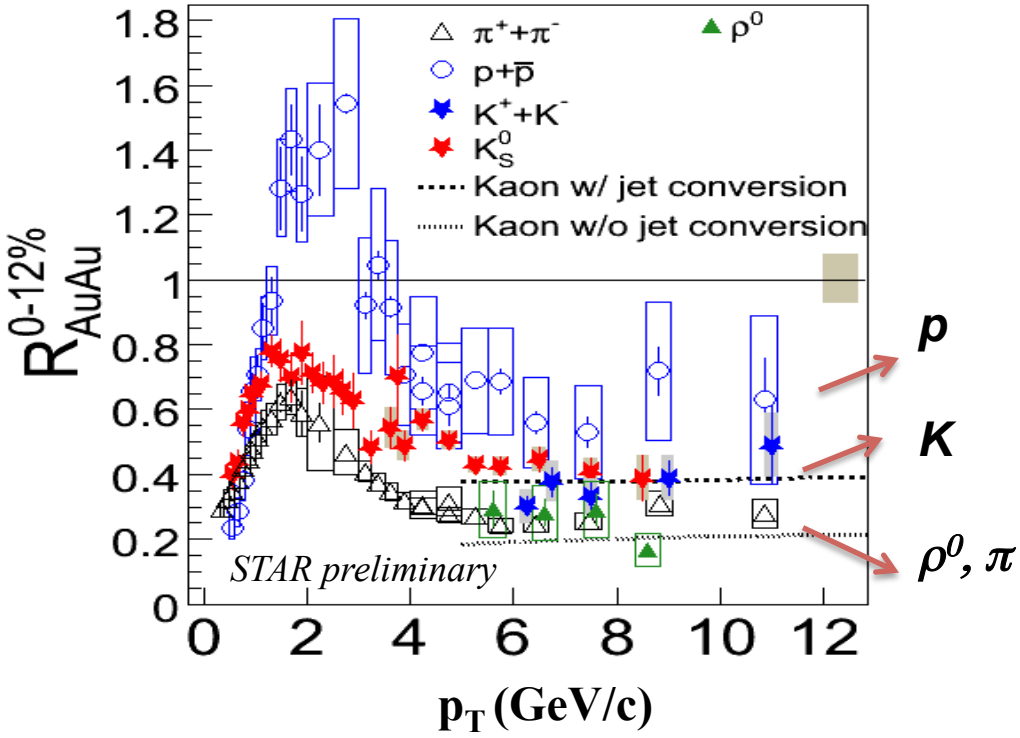
Low p_T (≤ 2 GeV/c): hydrodynamic mass ordering
High p_T (> 2 GeV/c): number of quarks ordering
s-quark hadron: smaller interaction strength in hadronic medium
light- and s-quark hadrons: similar v_2 pattern

=> Collectivity developed at partonic stage!

Flavor Dependence in R_{AA} and pQCD



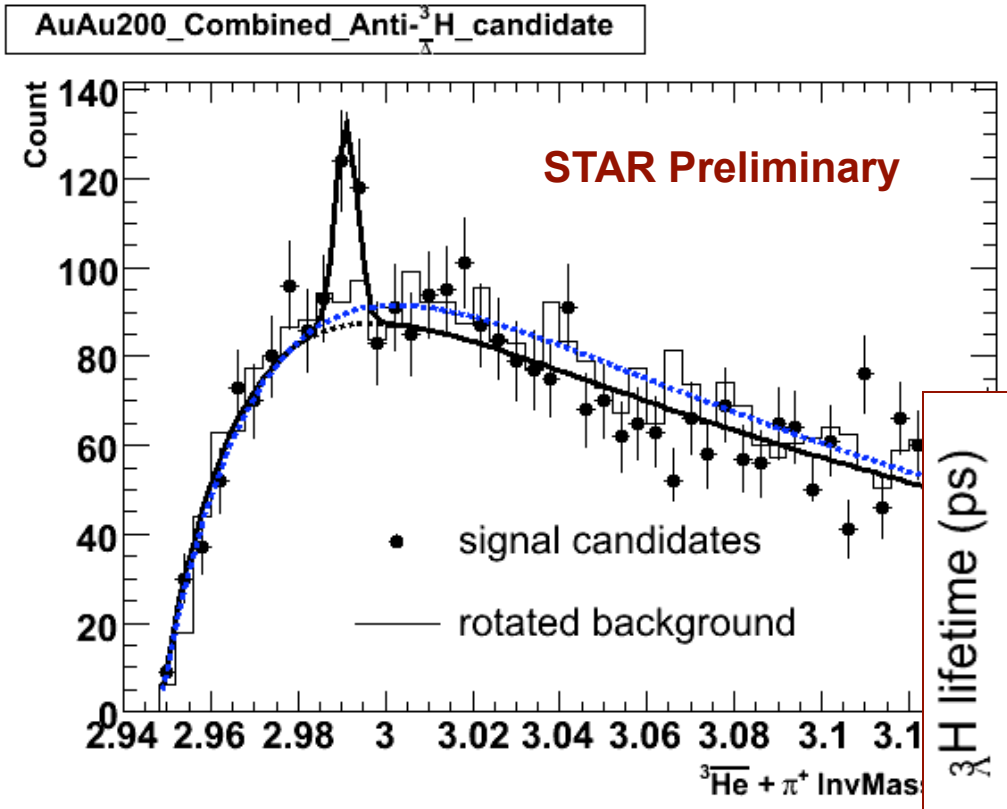
STAR submitted to PRL 0904.0439



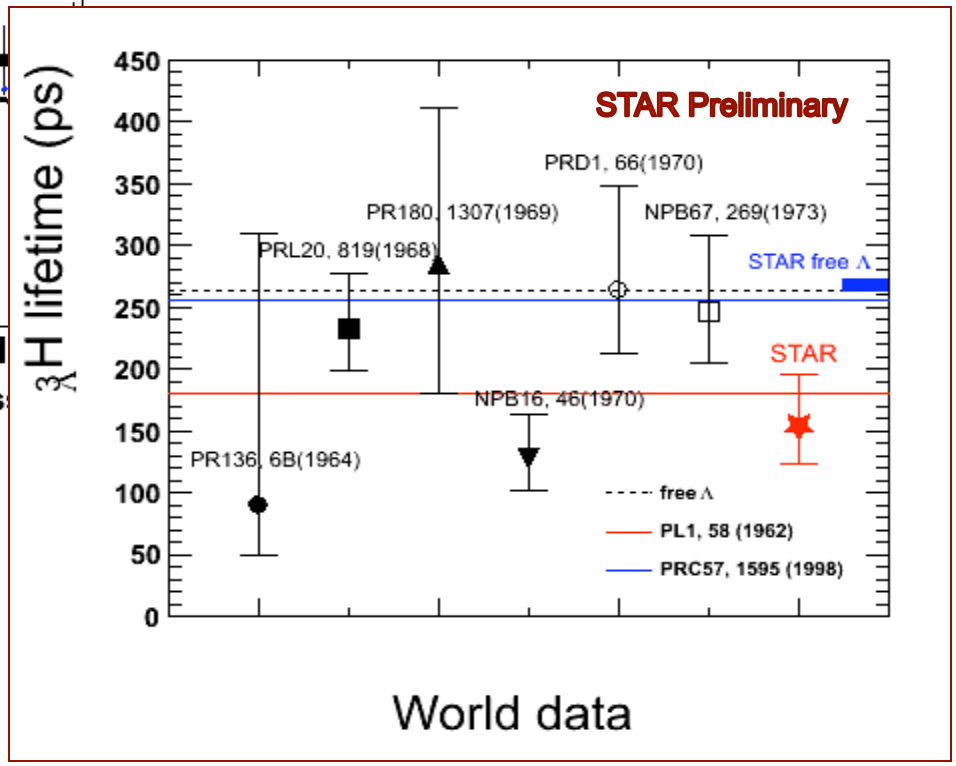
At $p_T \geq 5$ GeV/c: $\mathbf{R_{AA}(\pi) \sim R_{AA}(\rho^0) < R_{AA}(K) < R_{AA}(J/\psi)}$

ToF + TPC will improve the PID in future runs

First Observation of $^{3}_{\Lambda}\overline{H} \rightarrow {}^{3}\overline{He} + \pi^{+}$



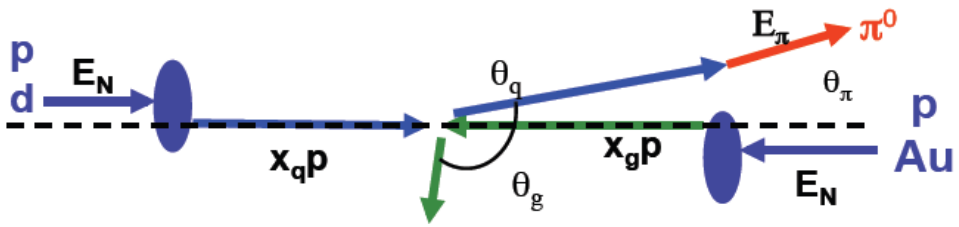
200 GeV Au+Au collisions at RHIC



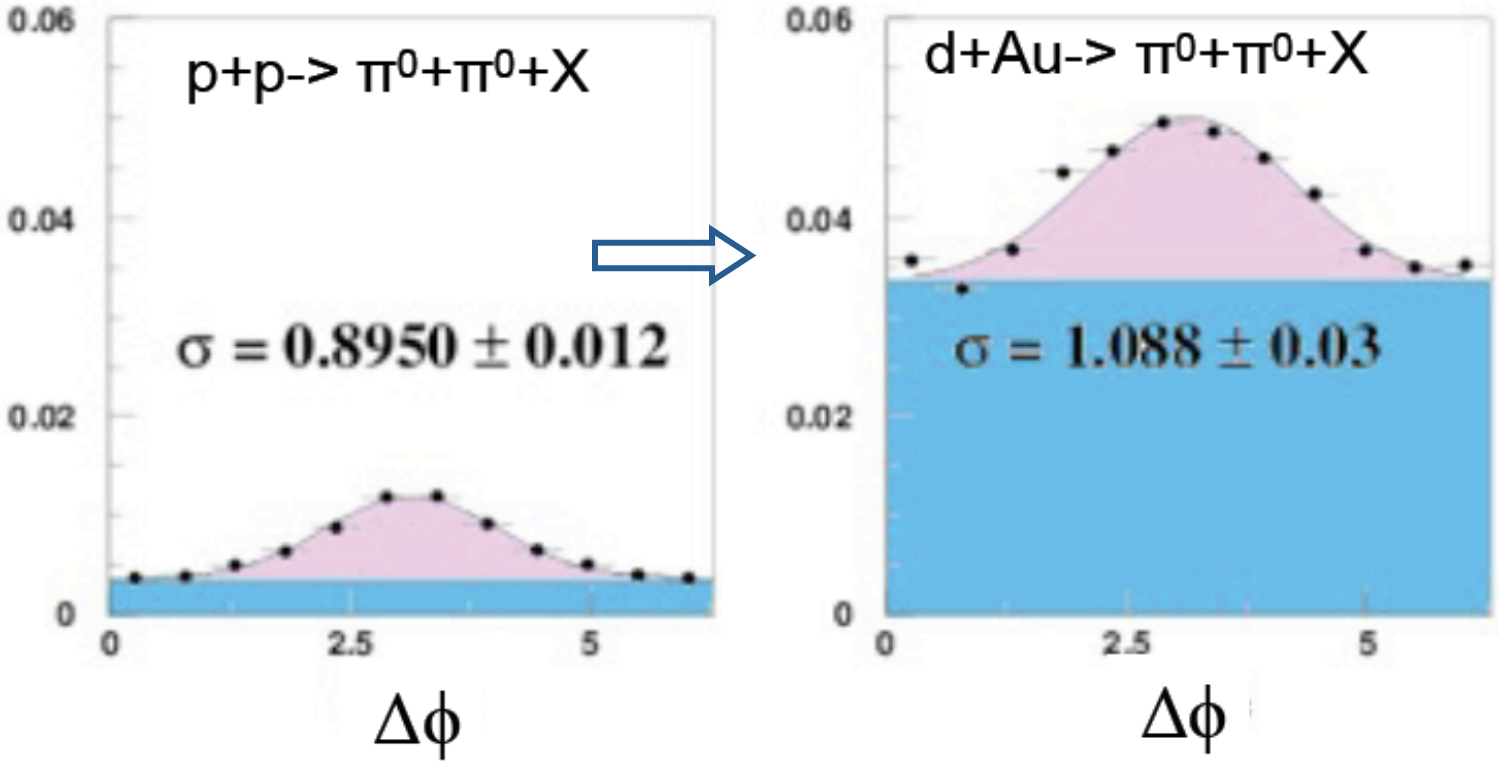
First observation of
an anti-hypernucleus

Paper draft in STAR review,
intended for the ***Science***

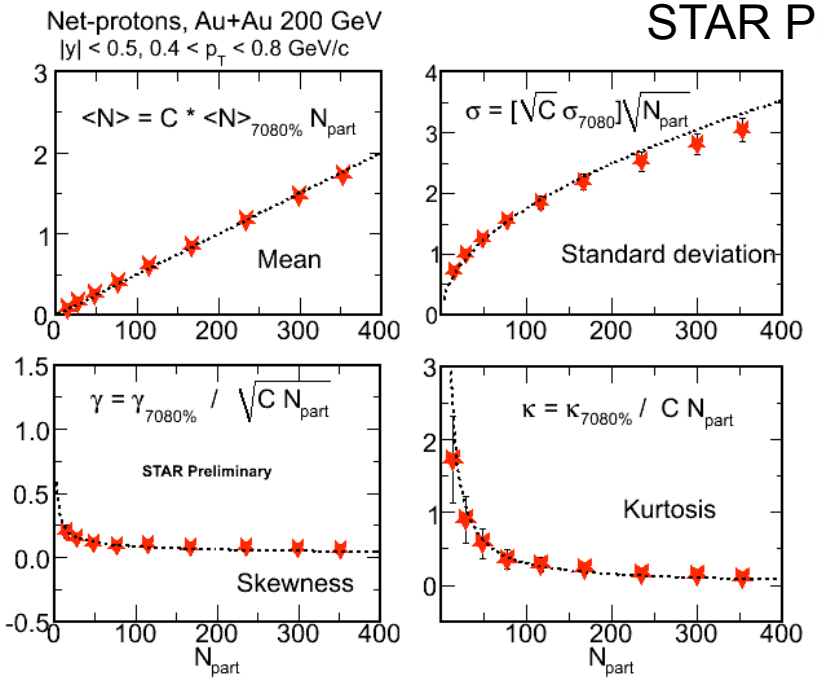
FMS – CGC Effect in Forward-y



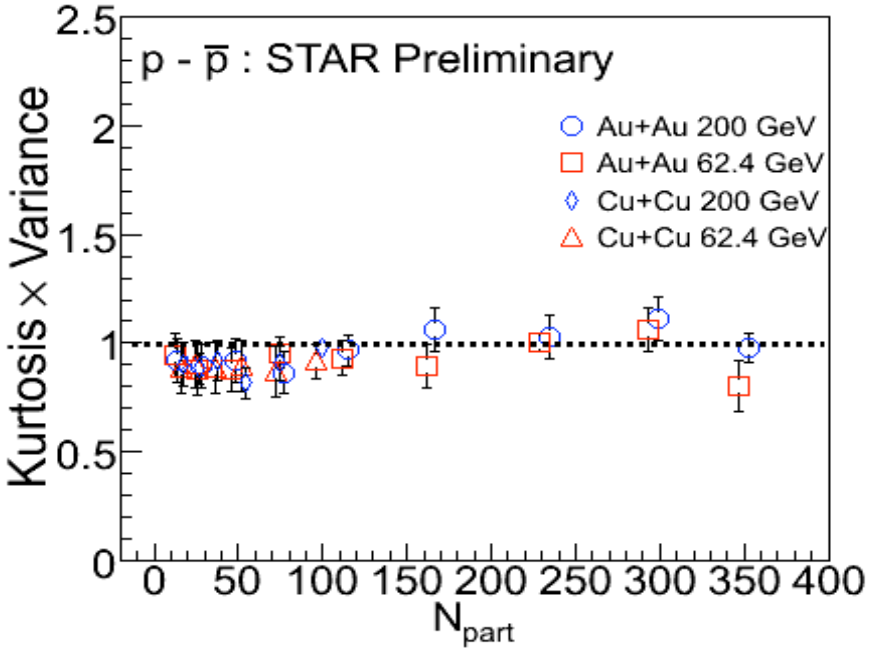
π^0 (FMS) - π^0 (EMC) correlation (Run8)



High Moment Analysis (BES)



STAR Preliminary, QM09

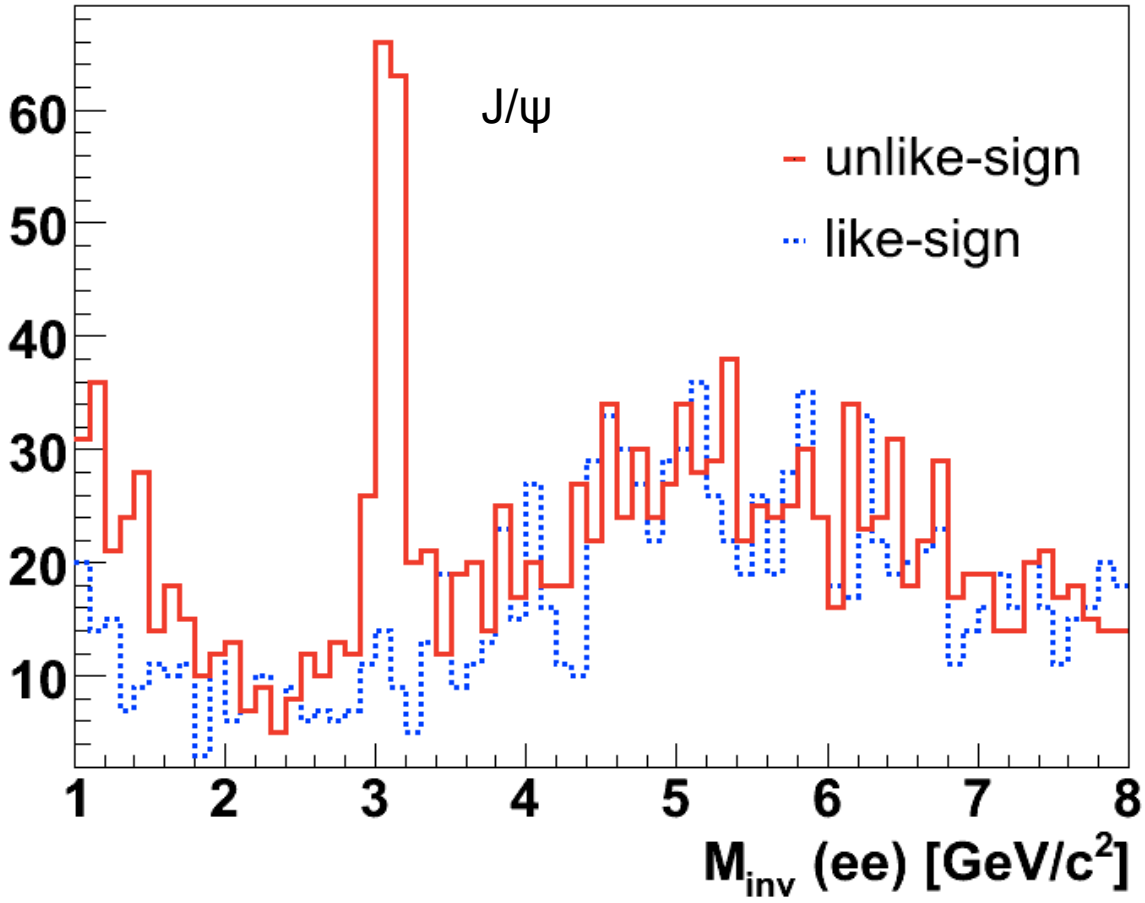


1) High moments are more sensitive to critical point related fluctuation.

2) The 4th moment, Kurtosis, is directly related to the corresponding thermodynamic quantity: susceptibility for conserved quantum numbers such as Baryon number, charge, strangeness…

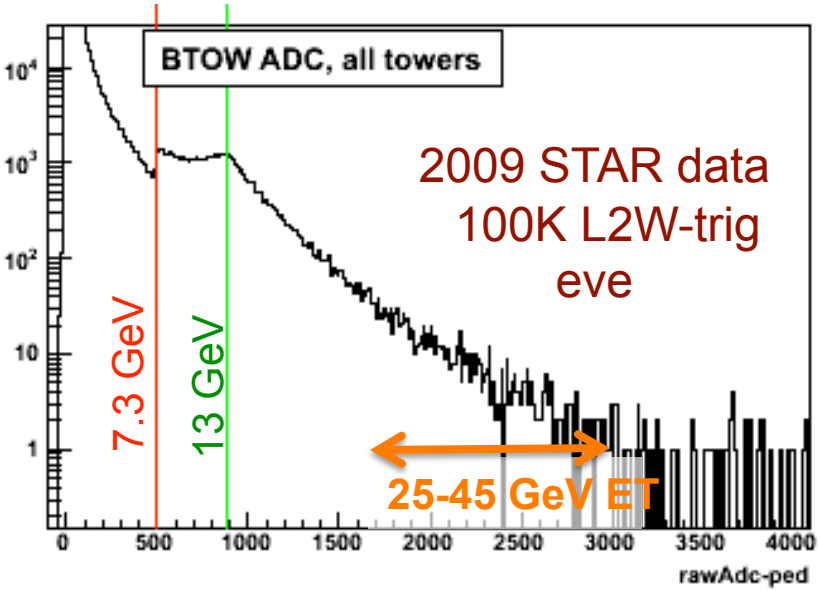
STAR High Level Trigger

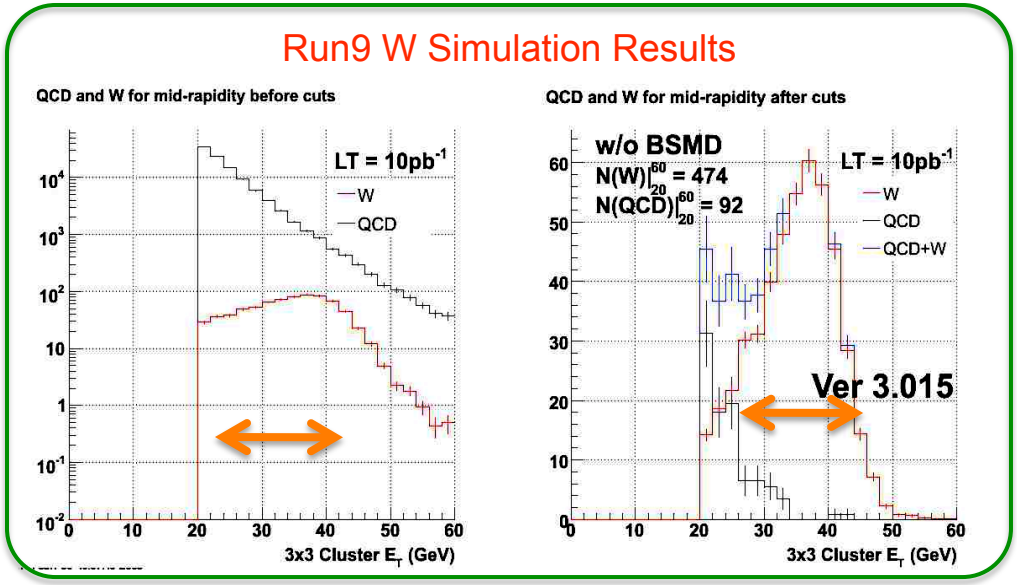
Run 9 p+p 200 GeV, May 19 - 25



1) Fast filtering for quick data analysis. Run10: try J/ψ v_2
2) Online QA

STAR mid-y W measurement





***W- trigger**: HT>7.3 GeV ET & L2: 2x2 >13 GeV, 2-3Hz*

Acquired since March 19 (longitudinal pol @STAR)

- *36 hours of STAR DAQ up time w/ W-trigger*
- *300K W-trigger events*

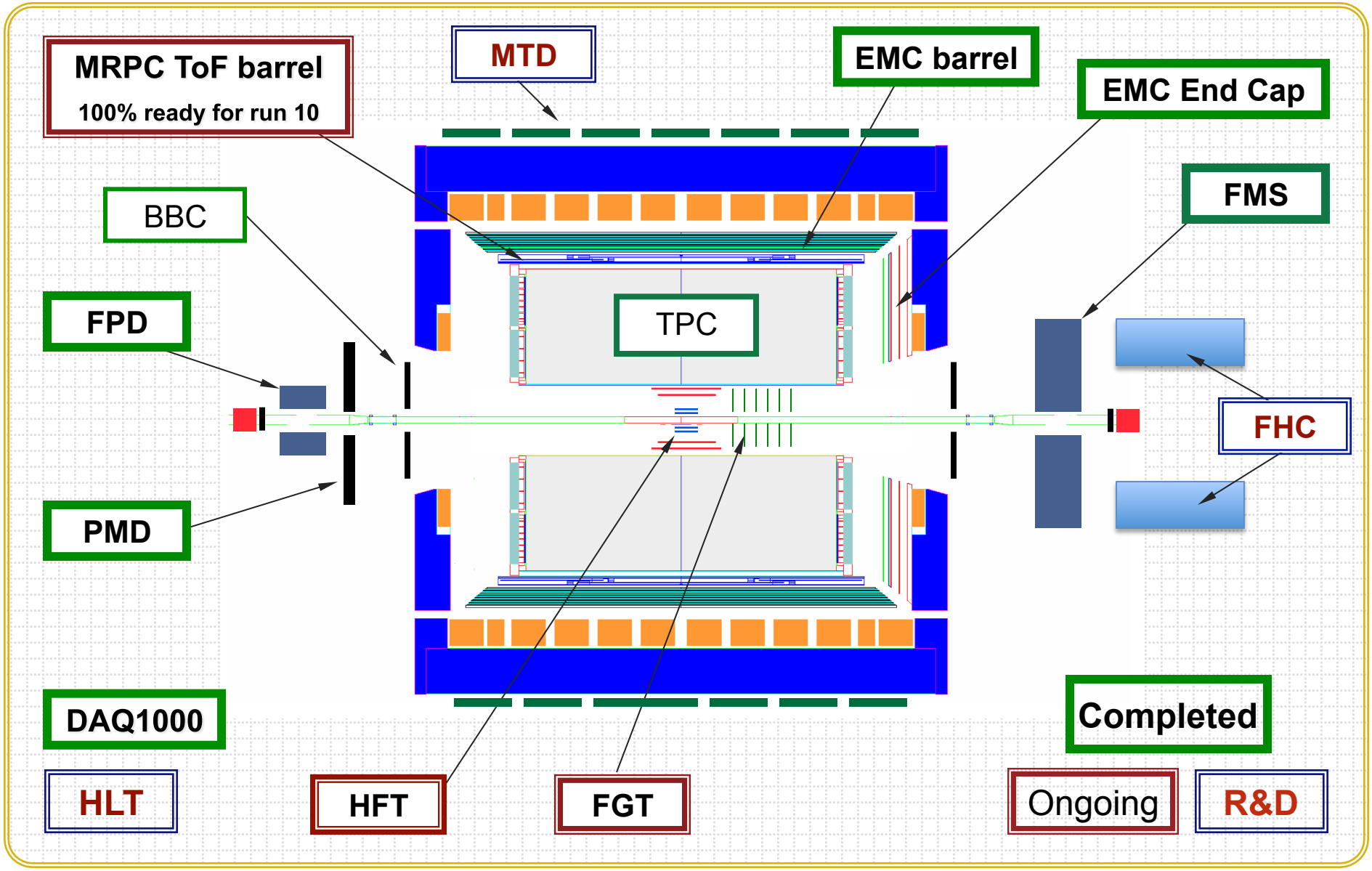
All events processed to muDst w/ crude TPC calibration

2009:

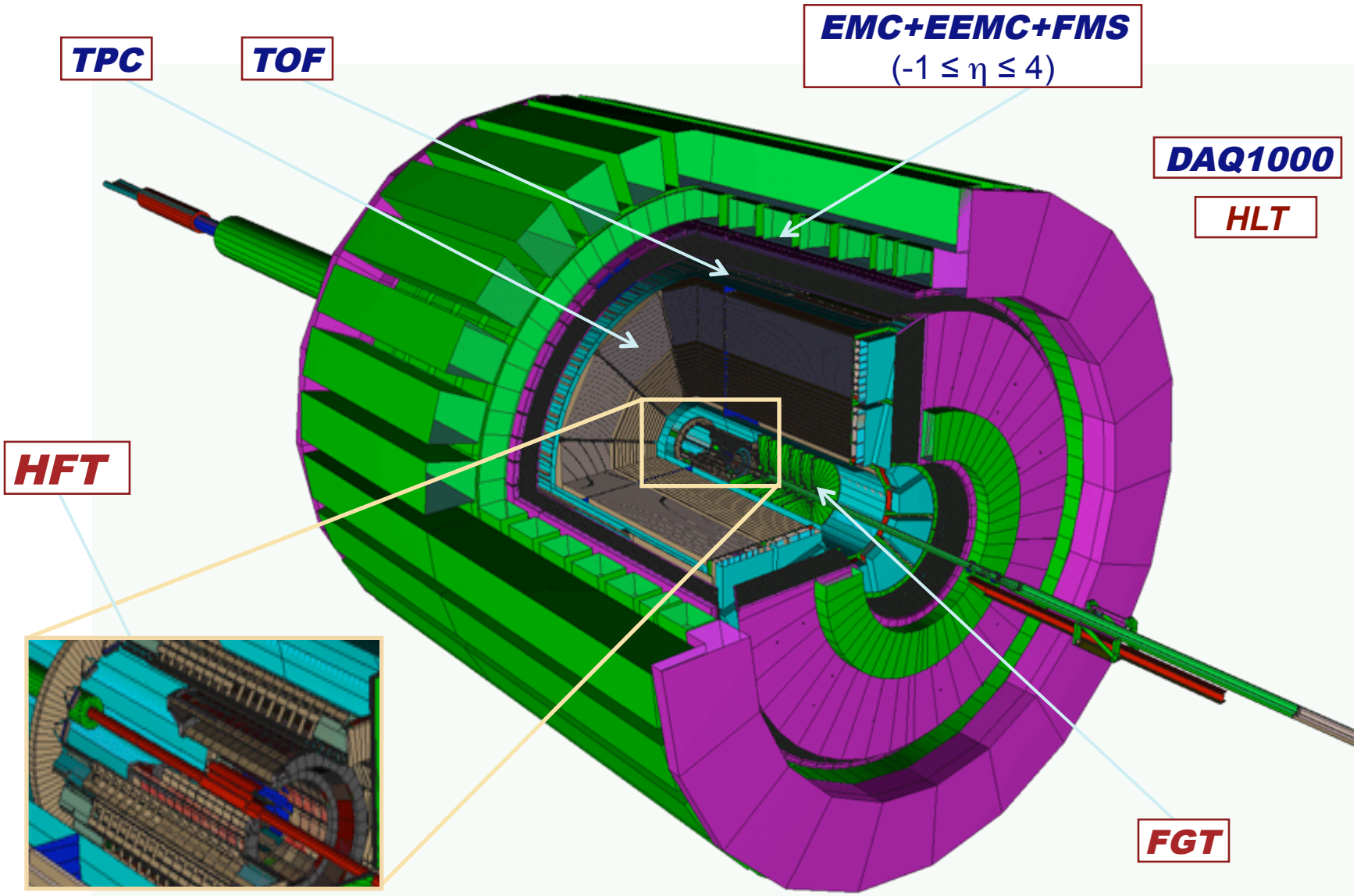
1. **W cross-section** , 10 pb^{-1} sampled
2. **W A_L** , long pol 50%

(achieved P=~30% → LT=~28 pb^{-1} sampled)

STAR Detector



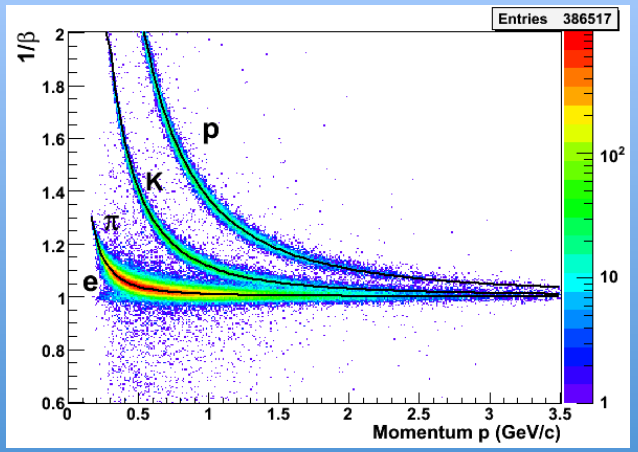
STAR Detectors: *Full 2π particle identification!*



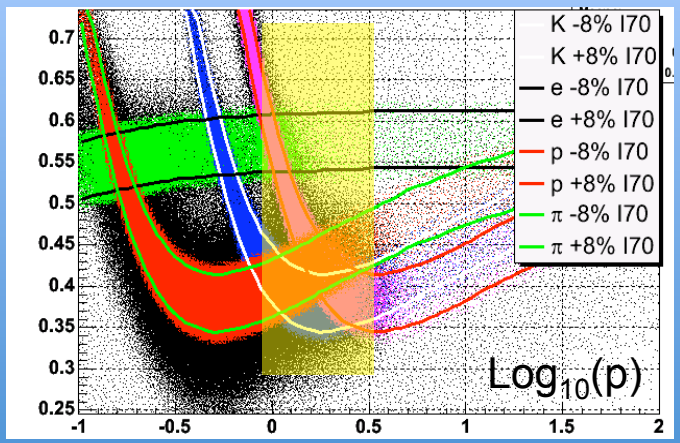
STAR: Physics with ToF

1) Significant improve PID. With TPC, PID has been extended to ~15 GeV/c.
2) Correlations with PID hadrons, resonances (up to Omega), jet triggered
3) Beam energy scan program: event-by-event K/pi analysis and net-p Kurtosis
4) 2π electron and di-electron analysis
5) …

STAR TOF



STAR TPC+TOF

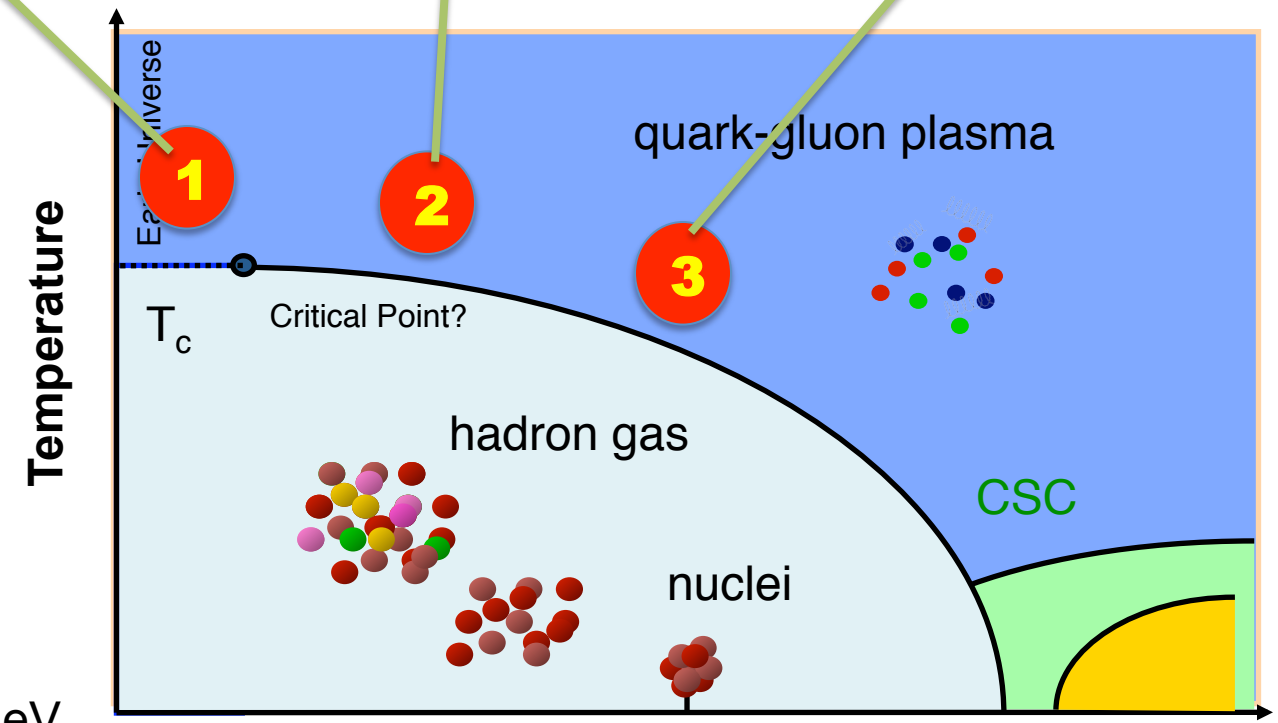


High-Energy Nuclear Collisions

1 **Energy Frontier**
T_C
LHC, RHIC

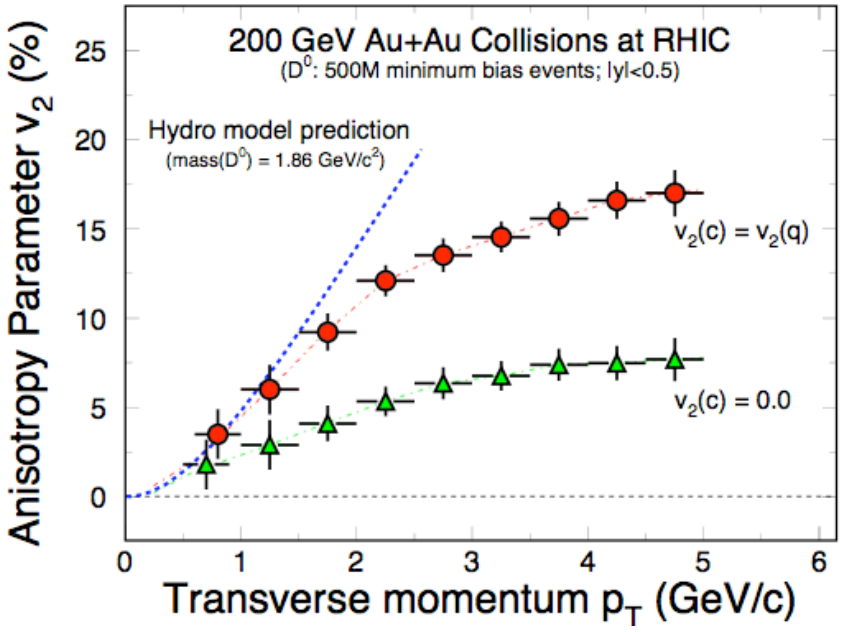
2 **Density Frontier**
T_E
RHIC, FAIR

3 **Baryon Density**
1st order p.b.
FAIR, NICA



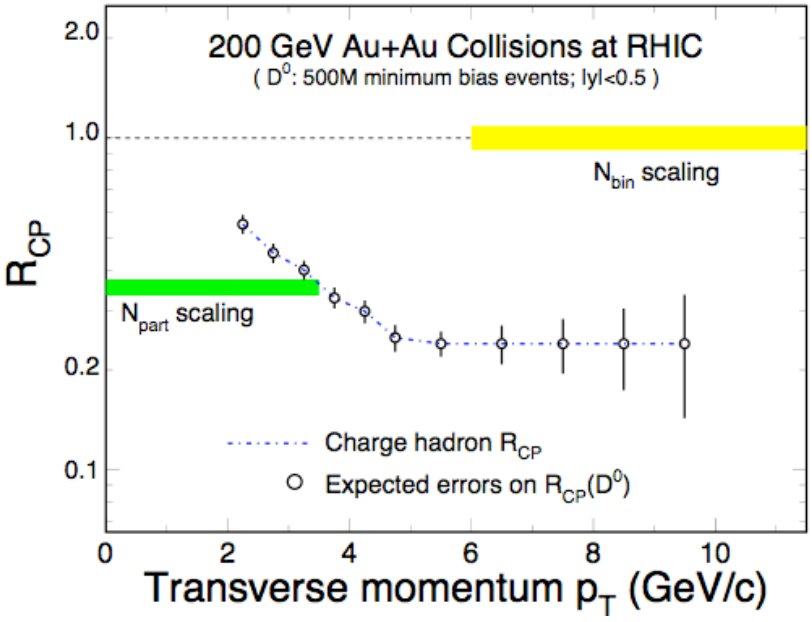
Run8: 9.2 GeV
paper in review

HFT: Charm Hadron v_2 and R_{AA}



- 200 GeV Au+Au m.b. collisions (500M events).
- Charm hadron collectivity ⇨ drag/diffusion constants ⇨

Medium properties!



- 200 GeV Au+Au m.b. collisions (|y|<0.5 500M events)
- Charm hadron R_{AA} ⇨

- Energy loss mechanism!
- QCD in dense medium!

3) Near Future Run Plan

(1) 200 GeV Au+Au collisions with full ToF (low material run)

200M central events / 300M M.B. events / 2 nb^{-1} trigger events

High p_T J/ψ and v_2 of J/ψ

Jet trigger multi-hadron correlation, PIDed correlations

Starting the di-electron invariant mass program

(2) Beam energy scan down to $\sqrt{s_{NN}}$ ~ 7 GeV

- Search for the QCD phase boundary and critical point

(3) Complete the measurements in 200 GeV longitudinally polarized p+p collisions

- $\Delta g(x)$, ***FOM = P^4L = 6.5 pb^{-1}***

(4) 500 GeV polarized p+p collisions

FOM = P^2L ~ 1.5 pb^{-1}

First measurement of A_{LL} for inclusive jets

First measurement of A_L for mid-y W production (W^+)

Global Fits with Inclusive RHIC Data

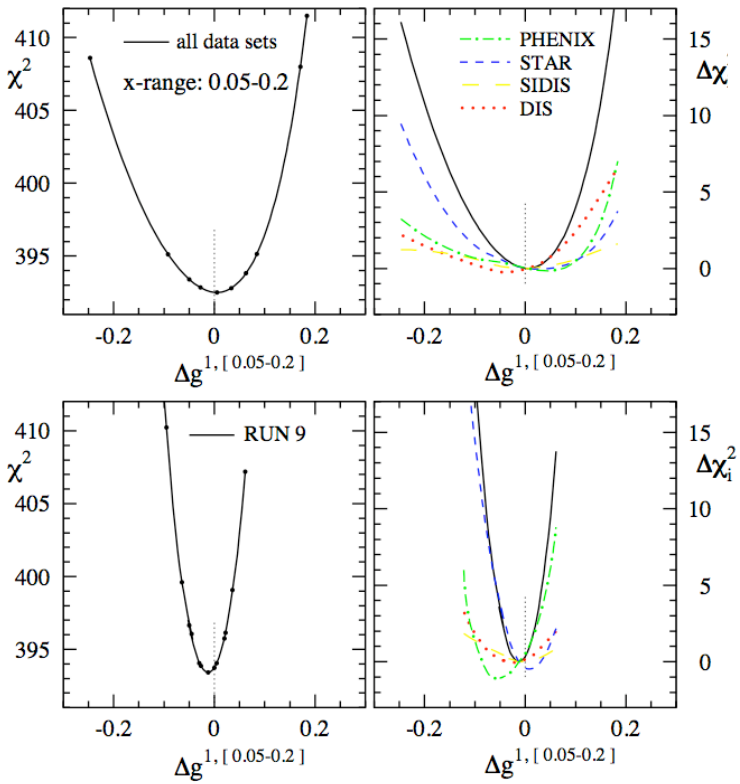
Run 9: STAR bottom line is to collect **FoM: 6.5 pb^{-1}** (Run9: 2.3 pb^{-1})

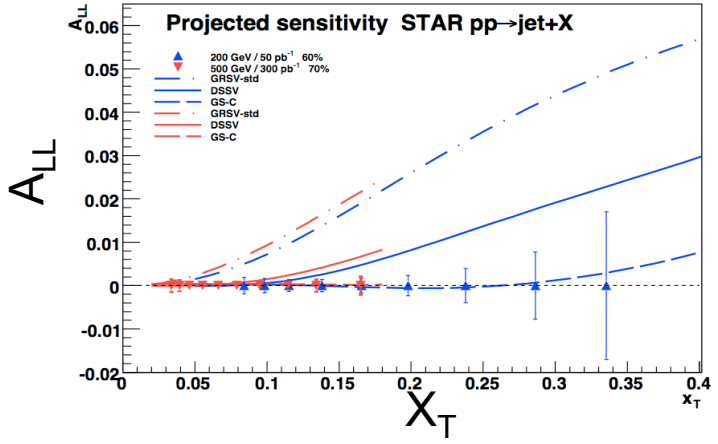
inclusive jet, di-jets, γ-jet… analysis

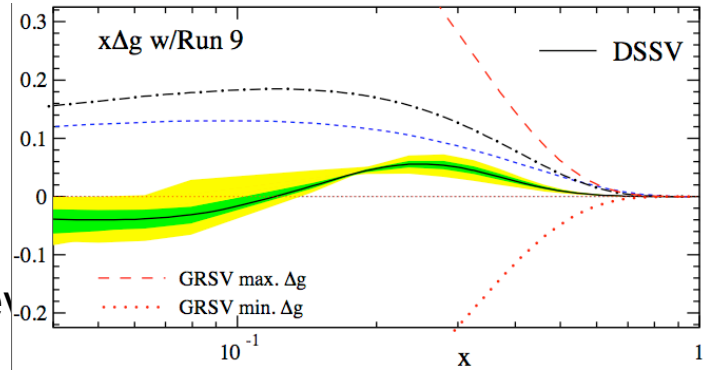
STAR: internal review of the *strategy* for spin physics in light of Run9. (Sichtermann, Sowinski, Surrow)

Run 6

Run 9







de Florian et al, arXiv: 0804.0422

4) Summary

1) STAR: a successful experiment for scientific discovery and an institution for training a new generation of physicists.

2) Upgrades have progressed well. Rapid physics outputs from upgrades ToF and DAQ1000, for example.

3) We have plan for future success but there are serious challenges: sufficient running time and beam quality.

Many thanks to BNL C-AD!

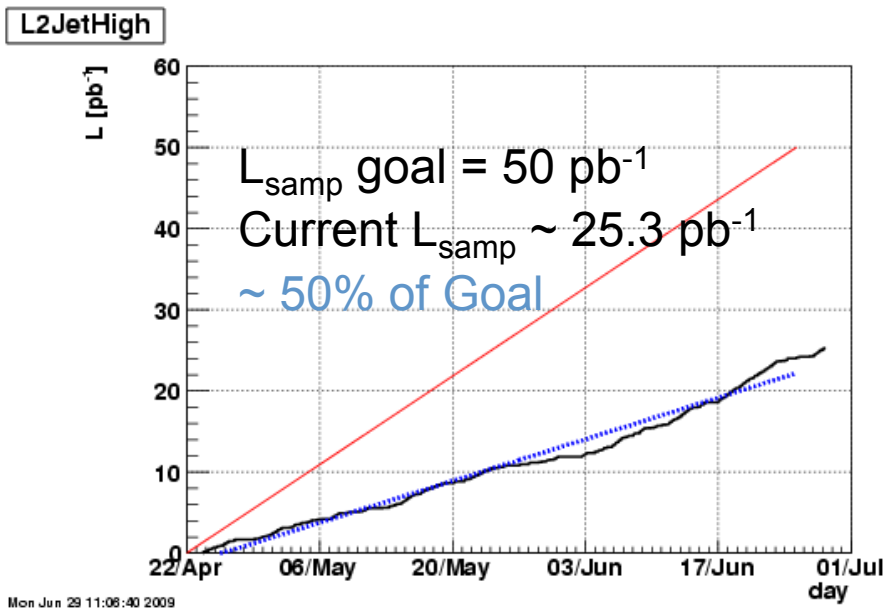
Many thanks to STAR BNL operation group!

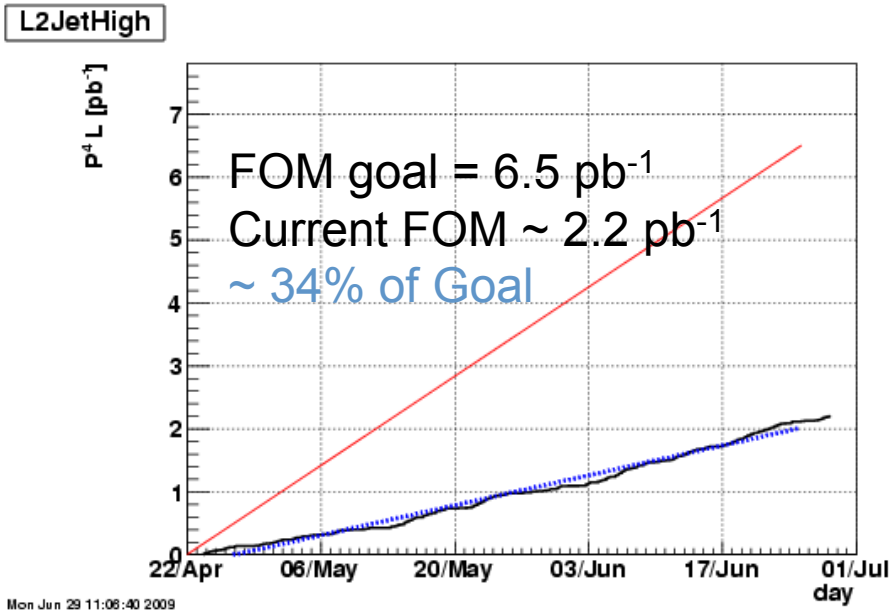
Many thanks to BNL management!

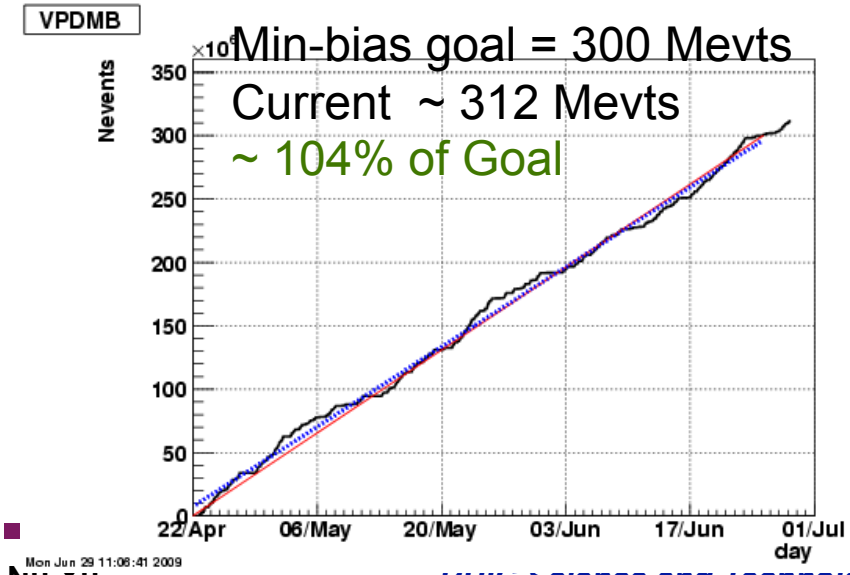
Many thanks to DoE NP for the year of good funding!

Backups

Final Summary of STAR Run 9 200 GeV Data accumulation







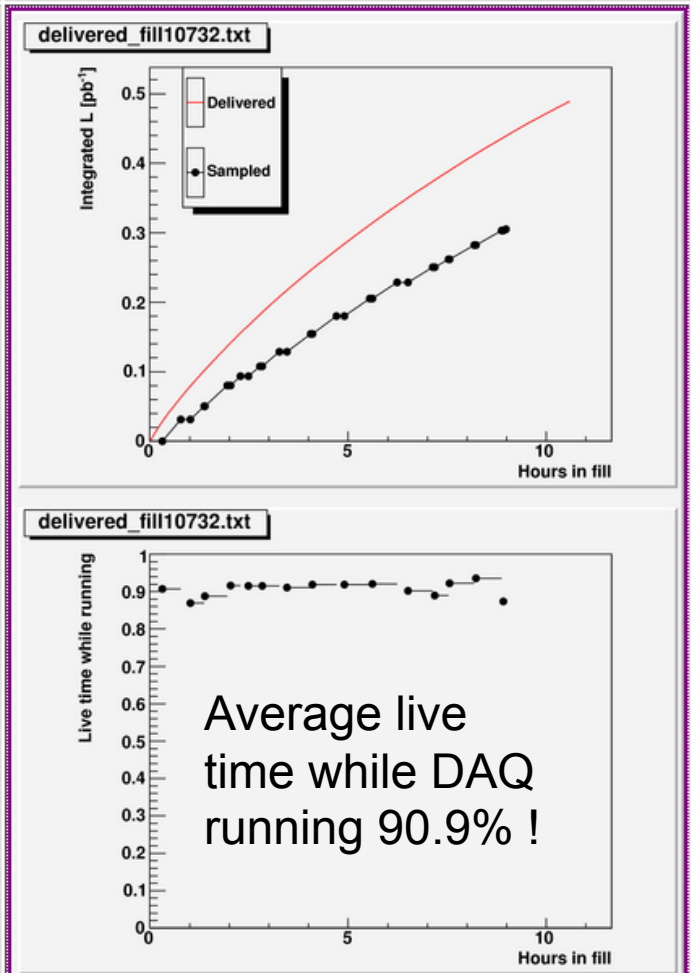
STAR efficiency for sampling the delivered luminosity was the best its ever been (primarily due to DAQ1000).

Appears that missing the pre-run goals may lead to further inquiry by DOE.

Retreat Input: Very important that Collider estimate performance as accurately as possible, and that Experiments achieve projected physics goals.

Example of STAR's "efficiency" for a RHIC Store

Fill 10732
Started Mon May 11 20:12:00 2009
Ended Tue May 12 06:48:00 2009
10.6 Hours
Total delivered: 0.489 pb^-1
Sampled Fraction: 0.624
Fraction of L delivered while taking data: 0.686
Fraction of hours delivered while taking data: 0.675
Hours lost before first run: 0.3 Frac: 0.030
Hours lost after last run: 1.6 Frac: 0.152
Luminosity fraction lost before first run: 0.058
Luminosity fraction lost after last run: 0.102
Average Live Time while taking data: 0.909

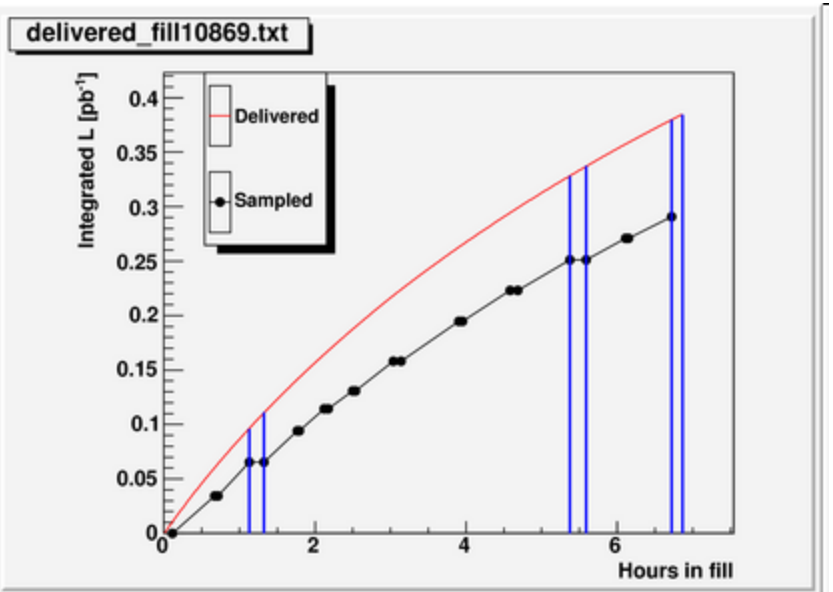


A few of the values listed/ calculated:

- Total L delivered 0.489 pb-1
- Sampled % = 62.4%
- % delivered while DAQ running = 68.6%
- % of hours while DAQ running = 67.5%
- Hours "lost" before first physics run = 0.30 (3%)
- Lum % lost before 1st run 5.8%
- Hours lost after last run 1.6 hrs (15% of store)!
- Lum % lost after last run 10.2%!

These efficiency statistics were calculated for all Stores after April 24th. Thanks to Peter Ingrassia for supplying Store data from RHIC. Input for Retreat: Important that Collider efficiently end stores!

Summary efficiency statistics



For the Entire 200 GeV run:

51.3 pb^{-1} delivered (C-AD 53.5)

	Lum.(pb^{-1})	Ratio/delivered
Sampled	25.3	47%
Turn on phys.	8.4	16%
After	3.6	7%
Lasers	5.4	10%
Deadtime	3.7	7%
Rest	7.1	13%

Important that Shift crews get trained (i.e. Physics all day on Tuesdays).

Important that physics running gets going before midnight!